

## Nanowires Increase Electron Conduction 100-Fold in Solar Cell

In a step toward less expensive and more efficient solar cells, the research group of MSD Scientist Peidong Yang has fabricated novel devices that conduct electrons from one end of the cell to the other about 100 times more efficiently than other nanoparticle-based solar cells currently under development. The new device consists of billions of nanowires, each about 60 nanometers in diameter and 20 micrometers in length and coated with a light-absorbing dye.

Although the use of solar power offers the possibility of abundant and clean energy, its cost remains high compared to the use of fossil fuels. In particular, despite over 50 years of R&D, the industry-standard silicon-based solar cells continue to be expensive. Recent progress in nanotechnology has created new opportunities for the fabrication of low-cost solar cell. However, the power conversion efficiency of nanoparticle-based solar cells is typically low. In most designs, the low efficiency can be traced to the poor connection between the nanoparticles and the external circuit; electron do not have a direct path but rather have to “hop” from particle to particle, leading to efficiency losses.

The approach taken by the Yang group was to fabricate cells with long (20 micrometers), 60 nanometer diameter single-crystal zinc oxide nanowires that run between the cell's electrodes to provide a direct path for electrons to move through the cell. The researchers constructed their nanowire arrays by seeding a conductive glass surface with ZnO “dots” three to four nanometers in diameter. By submerging the glass in a solution containing ZnO, wires could be made to grow from those dots. Optimization involved developing polymer additions to the solution to control the rate and direction of the wires' growth, ensuring that they remained perpendicular to the surface of the glass. A key challenge is to avoid having the wires touch the electrodes creating a short circuit. This too was achieved through control of wire growth. Coating the wires with an absorbing dye (a Ruthenium complex), filling the spaces between the wires with a liquid electrolyte, and applying a counter electrode completed the fabrication.

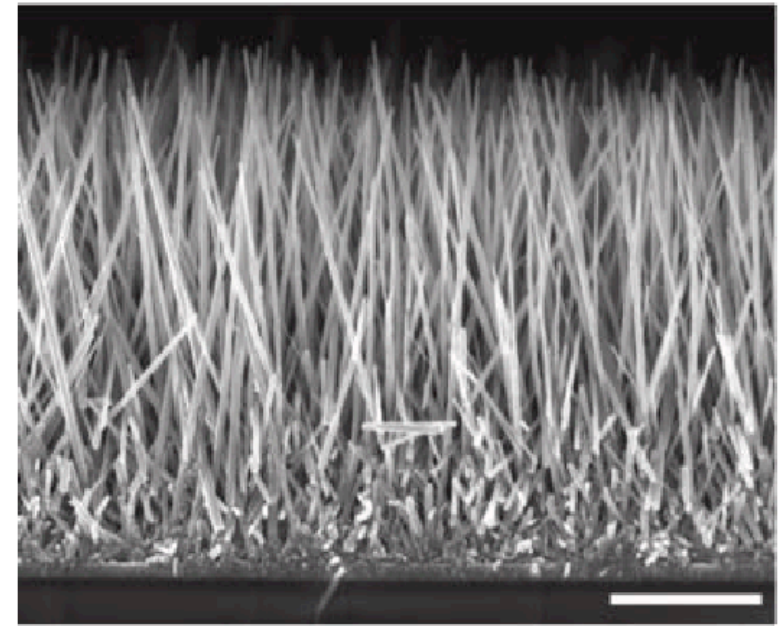
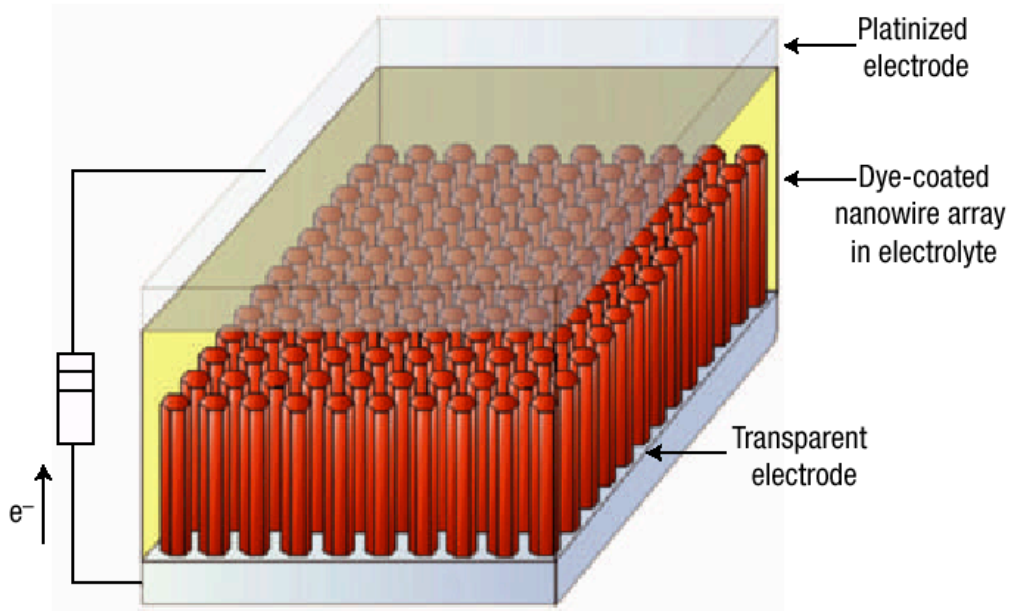
Single ZnO wires were extracted from the array and tested electrically. As noted, electron transport was found to be 100 times faster than in a typical nanoparticle-based solar cell. Using standard solar cell testing procedures, it was found that the overall light conversion efficiency (photon energy to electrical energy) was 1.5%, almost double that of typical ZnO nanoparticle based cell, but still lower than that of the commonly used TiO<sub>2</sub> nanoparticle-based solar cells (which have achieved efficiencies of up to 10 percent). The low efficiency was not a surprise; zinc oxide harvests electrons from the dye less efficiently than does titanium dioxide. As a result, the researchers are now making titanium dioxide nanowires, a more challenging manufacturing process. They are also shrinking the nanowires to 10 nanometers in diameter so more can fit into their arrays, increasing the total surface area to be coated with light absorbing film and efficiency. The team expects that with thinner and more numerous titanium wires, they will be able to achieve a conversion efficiency of 10 percent or more, which could make these nano solar cells a viable source of energy.

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M. Law, L. E. Greene, J. C. Johnson, R. Saykally, and P. Yang, “Nanowire dye-sensitized solar cells,” *Nature Materials* **4**, 455-459 (2005).

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**Nanowire solar cells based on ZnO.** Through the use of ZnO nanowires aligned along the current path (schematic, left), electron transport in the solar cell is improved by a factor of 100 compared to a typical nanoparticle-based cell. This increase in transport overcomes the fact that the ZnO nanowire array (right) has a smaller surface area to coat with light-absorbing dye than does a network of nanoparticles. As a result, nanowire cell efficiencies are double those of typical ZnO nanoparticle based cell. Efficiencies are, however, lower than those of  $\text{TiO}_2$  nanoparticle-based cells. Development of 10 nm titanium dioxide nanowires is expected to increase the surface area and light absorbing capability, providing a viable path to achieving conversion efficiencies of 10 percent or more, which could make these nanowire solar cells economically competitive.